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Effects of Flow Channel Blockage on DNBR of SMART Fuel Assembly

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1. Introduction

The main objective of core thermal hydraulic design of reactor is to assure the core has coolability and thermal integrity of fuel during steady-state and AOO(Anticipated Operational Occurrences). The fuel thermal integrity is assured when SAFDL(Specified Acceptable Fuel Design Limits) are not exceeded during any condition of normal operation, including the effect of AOO. The SAFDL, for conventional PWRs, are mainly determined to prohibit cladding overheating and fuel melting. In the case of SMART reactor, a main factor of fuel thermal integrity would be prohibiting cladding overheating by CHF(Critical Heat Flux) due to its low power density and low mass flux.

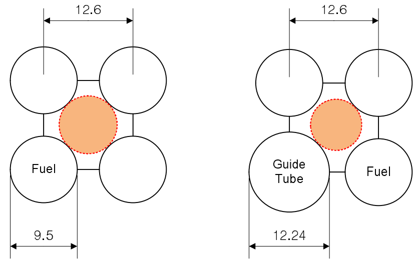
There may be obstacle objects that block flow area and threat the fuel thermal integrity by reducing coolability of coolant. The fuel thermal integrity should be maintained in that case. We evaluated effects of flow channel blockage on DNBR(Departure from Nucleate Boiling Ratio) of SMART reactor.

2. Blockage and Analysis Model

Most of debris would be captured by protective grid at the bottom of fuel assemblies. Flow channel blockage at the low part of the fuel assembly has known to have little effects on DNBR because flow redistribute rapidly at the downstream of blockage.

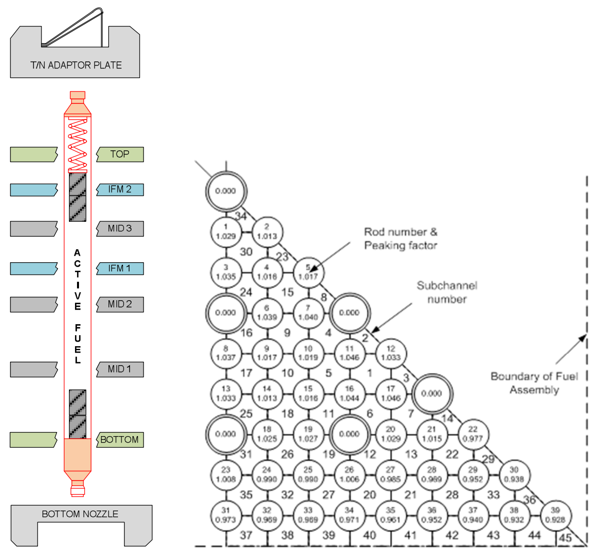
We evaluated DNBR of normal fuel assembly and blocked fuel assembly by an obstacle or two obstacles at active region. The locations of flow channel blockage are assumed that a cylindrical obstacle blocks flow area below one of five grids and two cylindrical obstacles block flow area below two of five grids. The shape of the obstacle is probably a cylinder to be able to move along flow path with maximum blockage ratio.

The maximum flow area blockage ratio would be obtained when cross section of the cylindrical obstacle is an inscribed circle in a subchannel. Figure 1(a) shows when the obstacle blocks the typical subchannel and figure 1(b) shows the obstacle blocks the guide subchannel. In the former case, the diameter of the obstacle is about 8.319 mm and free flow area reduces to 38 % of the original flow area. In the latter case, the diameter of the obstacle is about 6.949 mm and free flow area reduces to 50 % of the original flow area. We selected the former case in this study for the more conservative evaluation.



(a) Typical channel (b) Thimble channel

Fig.1. Flow Blockage by Cylindrical Obstacles.



(a) Fuel Assembly (b) Subchannel Model for 1/8-FA

Fig.2. Schematic Diagram of the Fuel Assembly and Radial Pin Power Profile.

A 45-subchannel model for a 1/8 symmetry of the hot fuel assembly and for MATRA-S[1] code were used for this study. 1.55 chopped cosine shape profile was applied as an axial power shape. The radial design pin profile of Westinghouse with peak power of 1.046 was applied as a radial pin power profile. Inlet mass flux reduced to 95% of nominal value for the hot fuel assembly. The Average heat flux was determined as an 187% of nominal value where the MDNBR(Minimum DNBR) is 1.511 which is close to the design limit CHFR(CHF Ratio) 1.5.

3. Results

DNBR along axial level without flow channel blockage is shown in figure 4(a). In this case, the MDNBR is 1.511 just below of 2nd mid grid and DNBR increases rapidly at the downstream of mid grids or IFM grids. Figure 4(a) also shows DNBR along axial level when a flow channel blocked just below 2nd mid grid. The MDNBR 1.367 and it occurs at the blocked location. This is the worst case when a flow channel blocked at one of five grids.

Figure 4(b) shows DNBR profile when a flow channel blocked at both of the 2nd mid grid and the 1st IFM grid at the same time. The DNBR decreases at the 2nd mid grid more than that at the 1st IFM grid. This is the worst case when a flow channel blocked at two of five grids. In all cases, worst MDNBR is evaluated as 1.367 and the value is far from the occurrence of CHF.

Figure 5 shows effects of inlet mass flux on MDNBR without flow channel blockage under nominal operating conditions. It shows that inlet massflux of the all subchannels in the hot fuel assembly should be reduced to 37 % of the nominal value to meet the limit CHFR 1.5.

The results of this study show that SMART reactor has enough thermal margins to maintain fuel thermal integrity for the flow channel blockage.

ACKNOWLEDGEMENTS

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REFERENCES

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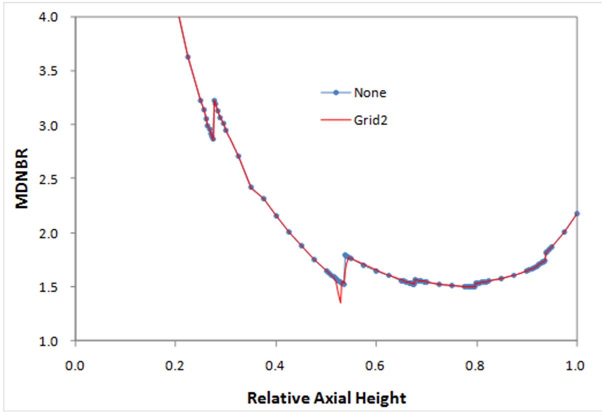
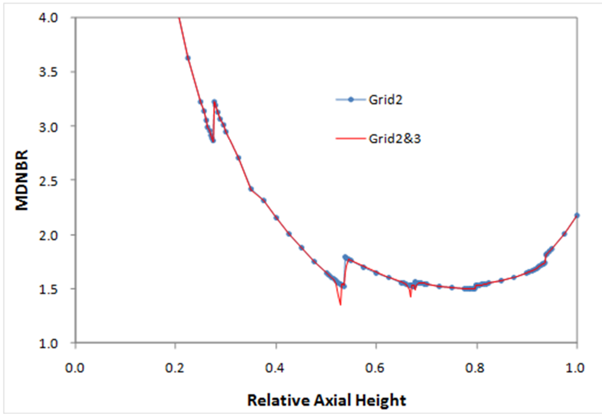
Table 1. Flow Blockages and MDNBR

MDNBR	No Blockage	1.MG1	2.MG2	3.IFM1	4.MG3	5.IFM2
No Blockage	1.511					
Single Blockage		1.510	1.354	1.412	1.447	1.511
1.MG1 &			1.367	1.416	1.451	1.510
2.MG2 &				1.354	1.354	1.354
3.IFM1 &					1.412	1.412
4.MG3 &						1.447



(a) DNBR of Flow blockage below Grid #2



(b) DNBR of Flow blockages both below Grid #2 and #3

Fig.3. Effects of Flow Blockage on DNBR

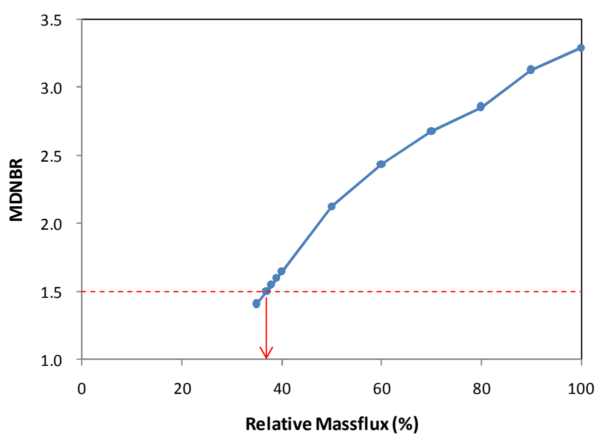


Fig.5 Effects of Inlet Massflux on MDNBR